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XXXVIII.—*On the Structure and Affinities of the Genus* Catagma*. By W. J. Sollas, M.A., F.G.S., &c.

[Plate XIV.]

In a previous paper I referred certain kinds of fossil Spongida (*Manon macropora*, *Jerea mutabilis*, *Scyphia foraminosa*, and others from Upware and Faringdon) to the group of the Renierida (Carter), on the ground that the calcareous fibres which form their skeletons are largely made up of long uniaxial spicules lying lengthwise in the fibre, and so far resemble the skeletal structure of *Pharetrospongia*. At the same time I was well aware that the fibres of the Faringdon sponges contain other kinds of spicules besides the simple acerates; but these I then regarded as accidental, and upon consulting Mr. Carter found that he agreed with me in thinking that a Renierid sponge might easily have imbedded some extraneous spicules in its fibres, after the manner of the Hirciniadæ, without thereby losing its Renierid character. But upon coming to work out these sponges in detail it was soon found that these second sets of spicules, from their abundance and definite position, constituted a peculiar difficulty; and the fact that Professor Zittel had, upon mature consideration, decided to place the Faringdon sponges with the Calcispongiæ on account of the presence of these particular spicules in them, led me to hesitate before reaffirming my previous conclusions, and to submit the whole subject to renewed investigation.

* Κάταγμα, worsted.

It is a matter of great regret to me that other duties have precluded me from finishing this work during the past year; but as Professor Zittel is about to publish another of his exhaustive monographs on the fossil sponges, this time dealing with those characterized by a reticulate calcareous skeleton, it seems, on the whole, best for me to publish at once the observations I have already made without waiting an indefinite period longer for fresh facts to come to light.

On examining a thin slice from *Manon macropora*, *marginatum*, or *porcatum*, one will observe an irregular network of anastomosing calcareous fibres, with rounded meshes filled up with crystalline calcite, the crystals of which radiate from the sides of the fibre towards the centre of the mesh. The edges of the fibre are usually coated with an opaque, granular or fluffy material suspended in the adjacent calcite; and the minute interstices between the infilling crystals of calcite are usually occupied by an insoluble yellowish-coloured mineral which has no action on polarized light. The fibres, under a magnification of 145 diameters, are found to consist of a brownish-coloured calcite, often fibrous in appearance, containing a number of spicular forms of two kinds, the most numerous of which are slender thread-like forms, 0·0003 inch to 0·0004 inch broad, but of indeterminate length, since in no single instance has a perfect spicule showing both ends been observed: the longest measured portions attain a length of 0·012 inch; how much longer an entire spicule would be we have no means of judging.

These spicules are sometimes straight or nearly so (Pl. XIV. fig. 5), but more usually bent, either in a gentle curve parallel to the curvature of the fibre (Pl. XIV. fig. 2) or in several curves so as to become undulating (Pl. XIV. figs. 3 & 4). Sometimes they are abruptly bent in somewhat angular turns (Pl. XIV. fig. 3). They are not so crowded together as in *Pharetrospongia*, but, lying further apart, somewhat resemble a number of pieces of thread floating in a viscid medium.

The second kind of spicules is indicated by sections which have very different shapes according to the direction in which they traverse the spicule. The simplest shape of all is a circular space (Pl. XIV. fig. 9) which is filled with colourless transparent calcite, and is of course a transverse section through a more or less cylindrical shaft. In the centre of this circular section there is very frequently visible a minute opaque spot, which appears black by transmitted light; it possibly represents the axial canal of the spicule. Transverse sections through the uniaxial spicules would have a similar form; but the two, independently of other differences, can be often distinguished by their great difference in size, the circles in question often attaining a diameter of 0·001 inch. As the sections through the cylindrical rods thus indicated vary from longitudinal to transverse, so different forms are produced. Next, one meets with a number of triradiate forms, sometimes with the three rays inclined to one another at an angle of 120°, sometimes less equally inclined.

The ends of the rays are frequently seen, and prove to have had an elongated conical form. The central space, from which the arms radiate, frequently shows a cut surface, eminently suggestive of the former existence of a fourth ray which the section has removed. Thus, in Pl. XIV. fig. 6, we have the triradiate remains of a spicule with a cut surface in the centre, circular in shape, and certainly due to the cutting away of an arm which projected at right angles to the plane of the section. In Pl. XIV. fig. 14 the part cut away includes the upper part of the three remaining rays; and in this case we cannot say whether a fourth arm was originally present or not. So, again, the form of fig. 7 is inconclusive; the cut surface looks rather as if taken from one of the rays (*r*) still remaining than from one once at right angles to them. Even if this were the case, there is still a possibility of a fourth arm being given off on the opposite side, which should be visible on turning the section upside down. Unfortunately my slice is mounted on too thick a glass to permit of examination under a sufficiently high magnification to decide this point. Thus, though sections having a triradiate form abound in slices of the sponges under examination, it is only in certain cases that they indicate truly triradiate spicules. As the mounted slices of our sponges are not mathematical planes, but possess a sensible thickness, so it is possible to see something more than a mere section across a spicule; and thus we can very definitely make out the existence of numerous quadriradiate forms in the fibre (Pl. XIV. fig. 17). These very much resemble the spicules of a *Pachastrella* (Pl. XIV. fig. 13), one longer simple shaft dividing into three shorter simple arms at one end.

Irregular forms with apparently bifurcated rays are not uncommon; and one instance of a five-radiate spicule has been observed.

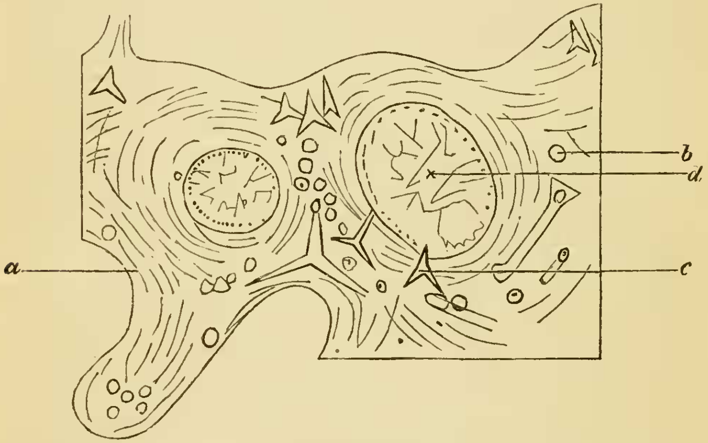
The shaft is not always straight, but sometimes becomes curved or even almost undulating (Pl. XIV. fig. 18); the rays likewise are sometimes curved (Pl. XIV. fig. 11). In size and in the relative length of the rays and shaft these spicules vary greatly. In some the rays are scarcely of larger diameter than the filiform spicules; in others they are several times as large, and appear giants by comparison.

The longitudinal sections of the spicules generally exhibit a number of opaque dots, usually irregularly dispersed; so that one of them occurring in a transverse section would simulate an axial canal cut through. This makes one less sure that axial canals really exist in these spicules; but since the dots sometimes take a linear arrangement in the longitudinal sections (Pl. XIV. fig. 16), they may, after all, indicate axial canals which have been partially filled up.

Relative Position in the Fibre of the two kinds of Spicules.

The filiform spicules chiefly occur in the outer part of the fibre, often forming the exterior third on each side, though sometimes less and sometimes, on the other hand, more of it, in some cases apparently occupying nearly the whole of the fibre almost to the exclusion of the other kind of spicules.

Fig. 1.



Section (partly diagrammatic) across fibres near the external surface of *Catagma macroporus*. (× 70.)

a, uniaxial spicules; *b*, transverse section of a multiradiate; *c*, echinating multiradiate spicules; *d*, interspace of a mesh, lined with granular material and filled up with calcitic crystallization.

The multiradiate spicules are usually axial in position, forming a core which is about one third the diameter of the whole fibre, though sometimes wider. This core looks, at first sight, like a congeries of irregular calcite crystals; but upon very careful analysis by the microscope it is seen to consist of circular and triradiate sections across the multiradiate spicules. It very frequently happens that one ray of a multiradiate is directed from the core outwards to the exterior of the fibre, beyond which it projects echinately, having crossed the longitudinal acerate spicules transversely in traversing the fibre. Sometimes a row of two or three multiradiates may be seen lying side by side, each echinating the fibre in this manner.

In one or two instances the fibres radiating towards and terminating against the surface of the sponge exhibit near their extremities a few multiradiates (Pl. XIV. fig. 20), which are disposed with their long shafts parallel to the axis of the fibre and their pointed terminal rays directed towards the exterior of the sponge. More usually the reverse is the case, however, and two of the rays lie transverse to the fibre, the other pointing axially outward. Sometimes, again, a triradiate form may be seen at the place of anastomosis of three fibres, sending a ray along the axis of each fibre.

The foregoing observations lead us to characterize the skeleton of *Catagma* in the following manner:—Skeleton consisting of an irregular network of fibres, now possessing a calcareous composition, built up of spicules of two kinds: one kind uniaxial, straight, simply curved or undulating, arranged longitudinally in the exterior third of the fibre; the other kind multiradiate (3- and 4-radiate), with the adjacent rays of each spicule making an angle of 120° with each other, or thereabouts; three of the rays occupying the interior or core of the fibre, the fourth directed outwardly and penetrating the layer of uniaxial spicules to echinate the exterior of the fibre.

Our next inquiry must be directed to determine the particular group to which this structure belongs. We have five orders to choose from, the Psammonemata, Chalinida, Echinonemata, the Tetractinellid division of the Holorhaphidota, and the Calcispongia.

The large proportion of structureless calcite occurring in the fibre seems to indicate the previous existence of kerataceous cement, which has since become replaced by carbonate of lime; but even if kerataceous material is so indicated, which is very doubtful, it cannot be taken as pointing to the Chalinida especially, since other groups of sponges, such as the Rhaphidonemata, also contain this substance. The Chalinida are, indeed, definitely excluded, not only by the presence of the multiradiate spicules, but also by the forms of the uniaxial spicules, which are quite inconsistent with Chalinid affinities.

The structure of the fibre is also unlike that of any Psammonematous sponge; but, in order to decide whether it might not have belonged to a sponge which possessed an Hircinian habit, thin slices of the Upware specimens, which include grains of quartzose sand in the meshes of their network, were examined. As the Hirciniadæ do not appear to discriminate in introducing foreign particles into their fibres, but pick up any minute grains which lie upon the sea-floor around them, so one would expect to find some of the quartz grains which occur in the meshes of the Upware sponges also present in the fibre had they possessed any affinities with the Psammonemata. Such quartz grains might easily be detected by searching with the polariscope; but a most careful examination failed to discover the least trace of them. Thus we eliminate the Psammonemata; and we have next to consider the Pachastrellidæ, to the trifid spicules of which the multiradiates of our sponges offer the closest resemblances.

In no Pachastrellid sponge, however, so far as I am aware, have we the curved and undulating uniaxial spicules of *Catagma*, nor is there to be found any definite fibrous structure. Thus we eliminate the Pachastrellidæ, the only Tetractinellid group of the Holorhaphidota that is worth considering. Far otherwise is it, however, with the Rhaphidonemata. The fibrous structure is not only common, but may be said to be characteristic of a vast number of this kind of sponges; curved and undulating spicules, very like those of *Catagma*, are also very frequent; and lately I have described a unique form (*Plectronella papillata*) in which triradiate and quadriradiate spicules, very similar to those we have been describing, are abundantly present.

One important difference alone (though certainly that is important enough) divides *Catagma* from the Rhaphidonemata; and that lies in the fact that the echinating multiradiates of the former form the core of the fibre instead of merely coating its exterior; but this is no more than the difference which distinguishes the Axinellida from the Ectyonida, the two families of Carter's order Echinonemata; and there is no difficulty in conceiving that, just as *Plectronella* presents us with a new departure in the Ectyonida by the substitution of multiradiate for uniaxial echinating spicules, so *Catagma* may represent a similar departure in the Axinellida.

This certainly is the view which I feel disposed to take; and so important does this substitution of multiradiate for biradiate echinating spicules seem to me, that I propose to elevate my group Plectronina to the rank of a subfamily in the Ectyonida, and to make the extinct *Catagma* the representative of a subfamily in the Axinellida. The classification would then stand thus:—

Order RHAPHIDONEMATA (Carter).

Family **Ectyonida** (Carter).

Subfamily *Plectronellida* (Sollas).

Family **Axinellida** (Carter).

Subfamily *Catagmida* (Sollas).

There now remain for consideration the counterclaims of the Calcispongia, which find an advocate in Professor Zittel, with whom it is my misfortune on this sole point to find myself in disagreement. The occurrence of triradiate spicules in *Catagma* appears, independently of its chemical composition, to be the only point in which it resembles the Calcispongia; in the structure of the fibre, which is, after all, a far more important character, the difference is complete; and no calcareous sponge has yet been discovered which presents us with curved and undulating uniaxial spicules like those of our sponge. Moreover, while the axial canal of calcareous spicules is so small as to be almost invisible, that of the multiradiate spicules of *Catagma* is sometimes apparently indicated. Nor, in reference to this, can it be urged that the axial canal of a calcareous spicule would be likely to undergo an enlargement as it became subject to fossilizing processes. In the case of a siliceous sponge, it is true that on exposure to the carbonated water of the sea-floor, solution sets in and soon enlarges the axial canals of its spicules till they become visible. But while solution equally affects calcareous spicules, it does so in a very different manner: instead of the axial canal undergoing enlargement, the whole substance of the spicule resolves itself into a granular mass, from which the original structure is quite obliterated, and in which certainly no signs of a canal can be traced. Fig. 2 (p. 360), taken from a decomposing spicule of a *Leuconia*, will clearly show this.

So far as the zoological argument goes, then, it may be summed up thus:—

1. (*a*) No known calcareous sponge possesses a reticulate skeleton with definite fibres having a spicular composition.

(*b*) Such a structure is exceedingly common among the siliceous sponges.

2. (*a*) No known calcareous sponge possesses long curved and undulating uniaxial spicules.

(*b*) Siliceous sponges (ex. gr. *Phakellia*, Bwk.) frequently contain spicules of this form.

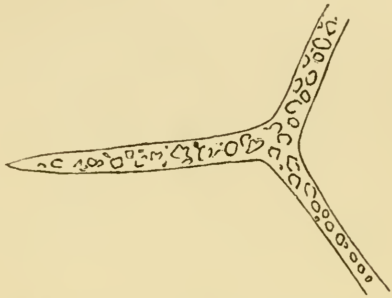
3. (*a*) Calcareous sponges usually contain triradiate and quadriradiate spicules.

(*b*) Siliceous sponges frequently contain quadriradiate, sometimes triradiate spicules (*Plectronella*; for other instances see my paper on *Plectronella*, in a forthcoming number of the 'Annals').

4. (*a*) Calcareous sponges are usually small, and seldom exhibit the external characters of *Catagma*.

(*b*) Siliceous sponges often closely resemble *Catagma* both in size and form.

Fig. 2.



Spicule of a *Leuconia* (× 435), to indicate the granular manner in which it begins to disintegrate.

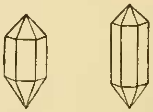
Next, and finally, we have to consider the mineralogical side of the question. Neither Professor Zittel nor myself doubt for a moment that siliceous structures may be converted during fossilization into carbonate of lime, and, conversely, that calcareous structures may become silicified: the only difference is as to which process has happened here.

We may observe, first, that while, on the one hand, we know of a vast number of cases in which siliceous sponges closely allied to existing species have been preserved in the fossil state, on the other hand not a single instance of a fossil calcareous sponge closely allied to any species of our existing seas has yet been described, the supposed fossil calcareous sponges differing widely in structural characters from existing forms. I have not, however, the slightest doubt as to the possibility and even probability of fossil calcareous sponges * being some day discovered. It is useless to allege that calcareous spicules are too unstable to survive the effects of such a feeble solvent as sea-water; that they soon disintegrate and lose their definite form when mounted in sections of the sponge

* *Protosycon*, Zittel, may be such a sponge.

to which they belong in Canada balsam is no doubt true, though even then they leave a thin transparent sheath behind, which, to some extent, maintains the original spicular form: no less true is it, according to Carter, that they break down when mounted dry or enclosed in the kerataceous fibre of a Psammonematous sponge; but when well cleaned by caustic potash and then mounted in balsam, they last much longer, and if placed in distilled water instead of balsam they will keep for years. I have now before me some calcareous spicules which were so prepared; and they are as perfect to-day, even to their points, as they were when bottled and put away four years ago. Thus there is no antecedent improbability about the preservation of calcareous spicules.

Fig. 3.



Quartz crystals left on dissolving Carboniferous limestone from Caldon Low, Derbyshire. (× 140.)

As regards siliceous sponges, we have, as has been said, numberless fossil examples, many of these often existing in a calcareous state; but it may be as well to note that when a siliceous sponge becomes calcitized in fossilization, the displaced silica is generally to be found somewhere not far off, either in patches in the sponge itself, or in granules or nodules such as flints in the surrounding matrix, or as chalcedony silicifying associated calcareous shells, *ex. gr.* in the Lias of the South-Welsh coast, or in minute dispersed crystals of quartz * (fig. 3), Devonian and Carboniferous. In compact strata, such as chalk or limestone, it may be taken as an almost invariable rule that the replacement of organic silica by calcite is always accompanied by a subsequent deposition of the silica in some form or other; and thus, if one finds flints, chalcedonized shells, or minute quartz crystals in such strata, one will naturally look for the remains of the siliceous organisms which supplied them, and one's search will seldom be unsuccessful.

On the other hand, when one finds large masses of such a

* Attention was first directed to these crystals by my friend Mr. T. Wardle, F.G.S., in a paper on "Limestone" read before the North-Staffordshire Field Club in 1873. They contain numerous irregular internal cavities, and are frequently twinned. Left as an insoluble residue after the solution of the Mountain-Limestone by the great Permian denudation, they have accumulated to form sandstone beds in the red rocks of the Eden valley, to which my attention was directed by Prof. Morris. Similar but much larger crystals (0·02 inch long) are left on dissolving Devonian limestone containing the so-called *Stromatopora concentrica*, from Kingsteignton, near Teignmouth. These are completely riddled internally and much excavated on their faces externally by irregular cavities.

fossil as *Caunopora* forming limestone beds several feet in thickness, and no obvious deposits of silica associated with them, one may feel tolerably certain that these fossils have always possessed a calcareous and not a siliceous composition.

Now the importance of this observation is, that the Faringdon and Upware sponges do not contain any trace of silica, unless it enters into the composition of the yellowish, transparent, insoluble mineral which fills up the interstices of the calcitic infilling of the sponge. It would be difficult to make an analysis of this substance; and I could only observe in addition that it had no action on polarized light. If the fossils themselves are without any signs of deposited silica, so too are the surrounding strata; no mention is made of flint, chert, or silicified shells occurring in them in any descriptions which I have read. This, then, would certainly be a difficulty in the way of our interpretation, were it not for the exceptional character of the Faringdon and Upware beds; considering that these are deposits of sometimes loose, sometimes consolidated gravel, subject, in all probability, to current-action in a shallow sea during deposition, and to the free drainage of percolating waters subsequently, one could scarcely expect to find the silica from dissolved organisms retained in their immediate vicinity and deposited in the same way as it is in close fine-grained deposits of chalk and limestone.

Thus the mineralogical argument cannot, in this case, be said to favour either side, and we are left to depend on structural character alone. This to me indicates a far closer alliance with siliceous than calcareous sponges; and I wait with some expectancy for Oscar Schmidt's descriptions of the sponges brought home by the 'Challenger,' in the hope that new forms will be found amongst them to obliterate the only wide difference which now distinguishes *Catagma* from *Plectronella*.

It is not necessary to stay now to describe the outward form and general characters of *Catagma*; it is sufficient to refer to Sharpe's paper on the Faringdon sponges, and to indicate those forms which should be placed in this genus. They are as follows:—

Catagma peziza (Manon, Sharpe);
C. macroporus (Manon, Sharpe);
C. porcatum (Manon, Sharpe);
C. faringdonense (Manon, Sharpe).

In the family of the Catagmida must be included *Tragos faringdonensis* and *Scyphia foraminosa*.

I cannot conclude, however, without remarking upon the fact that Professor Zittel not only assigns the fibrous sponges with multiradiate spicules to the Calcispongia, but also the genus *Pharetrospongia*, in which none but uniaxial spicules exist. Now, whatever uncertainty exists about the Faringdon and Upware sponges (and I admit a great deal), there is, I am confident, none here. The proofs as to the nature of *Pharetrospongia* are, I believe, perfect; and should the Faringdon sponges eventually turn out to be genuine Calcisponges, I do not see how that can for a moment affect the position of *Pharetrospongia.*

Its structure differs in no important respect, except in the absence of flesh-spicules, which fossilization would inevitably destroy, from that of a recent siliceous sponge (*Pharetronema*, Sollas) which I have now before me awaiting description. Both are exactly similar in the size and shape of their spicular elements, in the arrangement of these spicules in a fibrous manner, in the thickness and character of the sponge-wall, in the form of the fibrous skeleton, and, finally, in the absence of obvious pores, oscules, and excretory canals. Were the two to be found together in the fossil state it would be difficult to distinguish one from the other, except by a very slight difference in external form. While this exact agreement exists between *Pharetrospongia* and a modern siliceous fibrous sponge (and similar sponges are amongst the commonest of our existing seas), there is no resemblance, but the most absolute difference, between it and any known form of the Calcispongia. Furthermore, we can fortunately, in this instance, adduce the mineral state of the sponge in support of the morphological argument, since the silica removed from its calcitized spicules has been deposited in the infilling material of its meshwork, and many, a great many, of its spicules retain their original siliceous composition.

So seldom does a calcareous organism in the Cambridge Greensand become silicified, and so constantly does *Pharetrospongia* possess both siliceous spicules and a silicified matrix, that one cannot regard the presence of the silica as due to its subsequent introduction. The manner of its occurrence and the perfect form of the spicules, which are still siliceous, leave no doubt in my mind, independently of the morphological structure of the sponge, that the original composition of these Cambridge sponges was siliceous and not calcareous.

With regard to *Pharetrospongia*, then, we have to take nothing upon trust, to make no assumptions, to imagine nothing; the evidence is as perfect in its separate links, and as complete in the union of these links, as it is in the nature of palæontological evidence to be.

Bristol Museum,
Sept. 30, 1878.

EXPLANATION OF PLATE XIV.

(Structure of *Catagma*.)

Fig. 1. Transverse sections of simple spicules of the skeletal fibre. (× 435.)
Figs. 2–5. Variously curved simple spicules, seen longitudinally. (× 435.)
Fig. 6. Quadriradiate spicule showing three arms lying in the plane of the section, and a circular cut surface from which the fourth arm has been removed. (× 315.)
Fig. 7. Triradiate form with a part cut away at *a*. (× 315.)
Fig. 8. Quadriradiate spicule, not fully exposed, but suggestive of a *Stelletta* spicule. (× 315.)
Fig. 9. Transverse sections of multiradiate spicules, exhibited at the place where the fibre curves at right angles out of the plane of the section. *a a*, edge of the fibre where cut across at the bend. (× 315.)
Fig. 10. Irregular form of spicule, terminating abruptly against the edge of the fibre *a a*. (× 315.)
Fig. 11. Irregular quadriradiate spicule. (× 435.)
Fig. 12. Quadriradiate spicule with bifurcated rays. (× 315.)
Fig. 13. Simple quadriradiate spicule, resembling in form one of the spicules of *Pachastrella abyssi*. (× 315.)
Fig. 14. Triradiate arms showing a cut surface at *a*. (× 315.)
Fig. 15. Curved terminal part of a spicule, ending abruptly against the edge (*a a*) of its fibre, through which it probably originally projected. (× 315.)
Fig. 16. Large, irregular quadriradiate. *a a*, edge of fibre in which it lies imbedded. (× 140.)
Fig. 17. Simple quadriradiate, showing all four arms. (× 315.)
Fig. 18. An irregular form of quadriradiate, one arm closely resembling one of the curved simple spicules. (× 435)
Fig. 19. Quinqueradiate spicule. (× 435.)
Fig. 20. Fibre (*a a a*) near the exterior of the sponge, with included multiradiates, some having the shaft directed inwards and the rays outward. (× 435.)
Fig. 21. Edge of a fibre showing an echinating quadriradiate seated close to the surface of the fibre, with one ray projecting outside it into the bordering granular deposit. (× 140.)
Fig. 22. Usual position of the echinating multiradiate in the fibre. *a a*, surface; *b b*, centre of the fibre; *c c*, transverse sections of similar multiradiates; *d*, projecting ray of echinating spicule; *e e*, simple spicules lying longitudinally in the fibre and crossing the echinating ray transversely. (× 435.)

XXXIX.—*On two new Species of Amphipodous Crustaceans.* By the Rev. T. R. R. Stebbing, M.A.

[Plate XV.]

Amphilochus Sabrinæ, n. sp.

The upper antennæ have the three joints of the peduncle short, subequal in length, the first two stout, the third very slight. The flagellum, of six articulations, is tapering, its first